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Recent Developments in Gas Street Lighting

By P. CRAWFORD SUGG, B.Sc.(Eng.), A.C.G.I., M.Inst.Gas.E.. *(Fellow).*

Summary

The economics of gas street lighting, particularly those for "Group B." have been greatly improved since the war by changes in the design and construction of the lanterns.

Considerable experience has now been gained of the performance in service of the new units. Their performance is consistent with the requirements of the new Draft Code of Practice for Street Lighting.

This paper describes the changes in design of lanterns and control gear which have been made, and reports the results of full-scale tests carried out on certain installations. Attention has been directed to improving both the performance and the daytime appearance of the lanterns.

Illustrations of post-war installations are given.

Contents

(1) SCOPE OF THE NEW WORK.

(2) IMPROVEMENT OF PRE-WAR LANTERNS.
- (2.1) Improvements in design.
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- (2.3) Service "duty" tests.

(3) NEW LANTERNS.
- (3.1) Group B lanterns.
- (3.2) Group A lanterns.
- (3.3) Control of gas consumption.
- (3.4) Simplification of controls.
- (3.5) Maintenance of the new lanterns.

(4) TYPICAL MODERN INSTALLATIONS.

This paper details the improvements and changes which have been made in low pressure gas street lighting equipment since the end of the war, and also makes reference where necessary to pre-war developments. The principal aim has been to simplify the maintenance of installations, and this has been achieved together with improved performance and more consistent operation. Some of the detail developments described here have also been applied to certain earlier designs of lantern which still have a useful life before them.

The pre-war equipment available included several designs of directional lantern which complied with the requirements of the Ministry of Transport for both Group A and Group B lighting. Many lanterns for Group A lighting made use of the horizontal linear source, and gave the very wide lateral spread distribution which is much used to-day. Some of the Group B equipment then in existence also gave very satisfactory results within the limits imposed by the spacing height ratio.

(1) Scope of the New Work

The essential requirement for meeting successfully competition from other illuminants lay, therefore, not so much in modifications to the methods of light control employed (although this subject has also received attention), but in design changes to permit simplified and cheaper servicing. Difficulties of nozzle and mantle supply at the end of the war meant that no changes in light source could be contemplated which departed from the use of the normal British Standard mantles or others already available.

There was also room for improvement in the daytime appearance of the pre-war equipment, particularly in the concealment of certain accessories.

Most engineers will be familiar with the type of circular gas lantern, still widely in use, which consists essentially of a cluster burner with ventilating arrangements, an enamelled steel reflector and a pear-shaped globe. Such a lantern has a symmetrical

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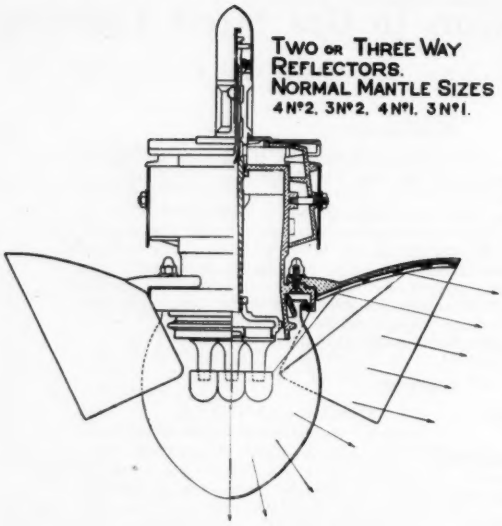


Fig. 1. Cross-section of a modern Group 'B' reflector lantern.

form of light distribution, and any directional equipment must, necessarily, be added to the basic design. Similarly, the traditional square lantern cannot be rendered directional without additional fittings, which may be subject to derangement in service. It is also noticeable that the square lantern, which has larger bulk and larger glass area that the globe lantern, contains the smaller light source.

The first line of approach, therefore, in designing new street lighting units, and one which has proved successful, was to produce a version of the globe lantern suitable for the sizes of light source commonly used for Group B lighting, incorporating in its design the necessary directional equipment. This type of reflector lantern, illustrated in Fig 1, first became available just before the last war. It will be noticed that the design is functional, the small size of the unit rendering it neat and unobtrusive in the street in daylight.

At about the same time a second lantern was produced primarily for main road lighting. This is shown in Fig. 2. Again, directional equipment was incorporated as part of the design and exercised effective control over the light output of the horizontal linear source, which consisted usually of 10 or 12 mantles.

Other designs of this period made use of concave anodised aluminium reflectors for light control.

At the end of the war a study of these existing designs was made to decide which types of unit should be reintroduced to the market. Detailed information was obtained on their relative maintenance costs and performance in service by the issue of questionnaires to many users, who co-operated very fully. The information thus obtained, coupled with direct practical experience and trial, showed conclusively that the small globe lantern (Fig. 1) was considerably easier and cheaper to maintain than the square lantern and, at the same time, gave a much improved and more consistent performance.

This general design, therefore, was worthy of further development. The questionnaire, however, revealed certain deficiencies of control which required attention.

The other type of directional lantern, in which reflectors were included inside the

body as shown in Fig 2, was more complex in construction, necessitating considerable care in cleaning.

This, therefore, was the position at the end of the war, and it is now proposed to show the steps in design which brought about the improved lanterns available to-day, both for Group A and Group B low-pressure gas lighting.

(2) Improvement of Pre-War Lanterns

(2.1) Improvements in Design

It is convenient to consider first the developments in design of Group B lighting units. Mention was made previously of the small globe type lantern, having external reflectors which has been found to be very effective, and economical in maintenance costs. In the pre-war form, this unit was normally mounted on a swan neck, giving a useful extension of mounting height. The control equipment was incorporated in a housing at the base of this swan neck, so that the clock controller was some four feet from the lantern and the leads to any ignition equipment were necessarily of similar length.

The first post-war change made with this type of lantern was to mount the control equipment adjacent to the lantern with less than a foot of tube between the two, thus enabling ignition leads to be reduced to little more than a foot. With this arrangement the control gear was warmed slightly by the heat from the lamp, so preventing the accumulation of any condensate within it. This arrangement also assisted maintenance by grouping together all components requiring attention. These small but useful improvements were made, however, at the expense of the appearance of the lanterns, the weather-proof clock controller being no longer housed out of sight. The next step in development, using the same lighting unit, was the introduction of mounting brackets in two distinctive designs, which themselves totally enclosed all the control equipment, i.e., constant pressure governor, clock controller, and ignition device. One of these designs was in concrete and suited a well-known column; the bracket was provided with a metal housing and door into which all control components conveniently

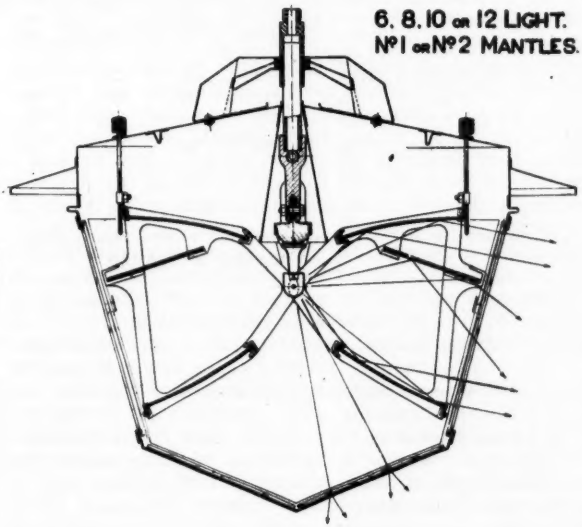


Fig. 2. Cross-section of a Group 'A' reflector lantern.

fitted. The other design was for a cast light alloy bracket having a lift-up top which provided excellent protection for, and access to the control gear.

That this change has improved the functional and aesthetic aspect of the design is shown by the selection of these new mountings for new housing estates and other lighting schemes, and by the passing of the alloy design by the Royal Fine Art Commission.

(2.2) Improvements in Performance

At the same time as these changes were made in the mechanical design, a higher standard of performance was achieved by improvements in technique and control in manufacture, including the photometric test of samples from each batch of glasses. This added control has led to remarkably consistent results from the mass-produced article. Table I shows the main characteristics of this type of lighting unit.

The design of the burner is such that it is almost equally efficient with mantle combinations having light outputs between 1,000 and 2,000 lumens, and it will operate on gases of any normal calorific value, points which were proved by sending specially calibrated test units to many parts of the country. A typical polar curve for the light distribution of this type of lantern is given in Fig. 3. Apart from producing effective road surface brightness, it will be noticed that this polar curve is free from irregularities in the lower hemisphere, so that no shadows are thrown by the lantern on the road.

The comparative performance of modern and older pattern gas lanterns for Group B lighting is shown in Table 2.

The change in the form of light distribution is indicated on the polar curve (Fig. 3) of the reflector lantern illustrated in Fig. 1; the dotted curve is the polar curve of an earlier directional lantern having the same number and size of mantles.

Table 1.

Photometric performance of improved Group B Gas Lantern.

Mantles		Total flux	Flux in lower hemisphere	Percentage of total flux in lower hemisphere	Total flux per cu.ft. per hour	Mean L.H. intensity	Peak intensity (at 80 deg.)	Directional intensity ratio
Number	Size	(lumens)	(lumens)		(lumens)	(cd.)	(cd.)	
4	B.S.2.	2100	1802	86	210	287	1020	3.5
3	B.S.2.	1764	1441	82	235	230	850	3.7
4	B.S.1.	1440	1195	83	230	190	730	3.84
3	B.S.1.	1070	894	84	225	142	560	3.95

Table 2.

Comparative performance of modern and older pattern gas lanterns for Group B lighting.

	New Unit	Old Unit
Lantern efficiency	230 lumens per cu.ft./hour.	160 lumens per cu.ft./hour.
Percentage of light in lower hemisphere...	83	75
Directional intensity ratio...	3–4	2
Polar distribution	Free from irregularities in lower hemisphere.	Interrupted by lantern framework.

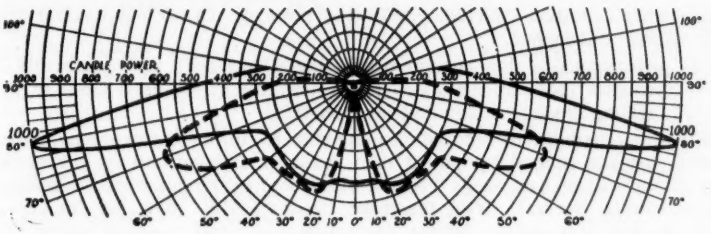


Fig. 3. Polar distribution curves in vertical plane of a modern Group 'B' lantern (continuous line) and an earlier directional lantern.

(2.3) Service "Duty" Tests

The Ministry of Transport Report, and the resulting draft Code of Practice for Street Lighting, use as a criterion of lantern light output the average lumen output of the clean lantern throughout the life of the source, this figure referring in the later document to light emitted in the lower hemisphere only. In practice, however, our atmosphere is not clean, and the term "clean lantern" can apply only to operation under laboratory conditions. It is therefore important to know the lantern performance under service conditions. Any loss of lantern efficiency due to the accumulation of dirt must add to that arising from depreciation of the source as it ages, the combined losses lowering materially the effectiveness of the installation and wasting energy.

Attention was therefore devoted to measuring the performance over a period of many weeks of an installation of the later designs of gas lanterns under normal district conditions but *without any maintenance.*

For the purpose of the following paragraphs, the term "duty" has been used to denote the light on the road at any given time, as a percentage of that obtained initially from newly-cleaned lanterns fitted with mantles which had been in use for about two weeks. The duty figure, therefore, allows for loss both by ageing of the light source (in this test all mantles were of the same "age," see note below) and by accumulation of dirt. The "duty" at any time was determined by averaging measurements of horizontal illumination at a considerable number of corresponding positions in each span. Readings were taken nightly whenever weather conditions permitted.

This laborious photometric work was largely carried out by the North Thames Gas Board. In addition, lanterns were arranged outside the laboratory in positions fully exposed to the atmosphere, and in such a way that the light from the lanterns could be reflected into laboratory photometric equipment where accurate recordings of light output could be made.

Similar lanterns were burnt indoors for the same number of hours to differentiate between depreciation of the source and depreciation due to dirt. The glassware on these lanterns was cleaned before each test, but no other adjustments were made.

The low pressure mantle light source itself has an average light output over life about 5 per cent. below the initial, but a cluster burner, having, say, four or six mantles, whose "lives" are usually out of step, shows less depreciation.

As far as gas lanterns are concerned, therefore, the chief factor affecting their duty is the accumulation of dirt on the glassware.

It was known from experience with older lanterns that a duty in service of 75 per cent. of the initial performance could be maintained, if necessary under penalty, with fortnightly attention. The tests on the new lanterns, however, demonstrate that a duty of 70 per cent. of the initial light output could be maintained under similar conditions, with a cleaning period of five weeks. These tests were made under severe

winter weather conditions (including snow) in London. In normal weather the duty was, of course, still higher.

This performance is thus consistent with the 60 per cent. (and preferably 70 per cent.) maintenance requirements stated to be desirable in the draft Code of Practice on Street Lighting recently distributed for comment.

While the possibility of reduced cleaning showed an obvious economy, it was still necessary with the control equipment then available to wind and set the clock controllers at intervals of two weeks. A new clock controller requiring attention only at, say, four-weekly intervals, was therefore needed. The controller makers were approached, and as a result a 42-day movement was incorporated in a new series of controllers. Experience with this movement, which had previously been used for the control of electric street lighting, showed that it could be expected to keep time within plus or minus six minutes over the period of 42 days for which it would operate. The chief difference in the design of this movement lay in the inclusion of a double main spring. With this controller the task of tappet setting is avoided by the use of the automatic solar dial, which requires setting only initially to the month and day of the month.

The next problems in the use of these lanterns in practice lay with those responsible for industrial relations. It is only necessary to say here that a satisfactory agreement was made with the trade union concerned, the union agreeing that it was fair and reasonable to double the number of these new lanterns compared with the number of those of earlier design in the care of each man.

(3) New Lanterns

(3.1) Group B Lanterns

From Table 1 it will be seen that the external reflector lantern already mentioned was designed with a maximum light output of 2,100 lumens, corresponding at 120-ft. spacing to 1,750 lumens per 100 ft. linear, and at 150-ft. spacing to 1,400 lumens per 100 ft. linear. For the upper range of Group B lighting a lantern of greater output was required which would include the advances already made.

Further advantages which it was hoped to incorporate in the design of this new lantern were a good external appearance and simplicity of construction. It was decided, therefore, to control the main light distribution by the use of diffusing or refracting glassware. A small refractor plate 12 in. by 5¼ in. having an oval pattern of prisms was produced, giving a peak intensity of some 1,500 candelas, with a considerable lateral light spread. The lantern into which these plates were built is illustrated in Figs. 4 and 5.

The shape of the cross-section of this lantern avoids undue heat stress on the glassware, while the size of refractor chosen is reasonably low in first cost, and is well able to produce the desired intensity at about 80 deg. from the downward vertical. The angle of maximum intensity can be pre-set at the desired value by vertical adjustment of the position of the light source. Lateral adjustment of the source similarly produces an assymetric distribution.

To obtain the desired shape of the polar curve the optical axis of the prisms is near the lower edge of the refractor plate, and the inclined bottom glazing of prismatic glass directs some of the light passing through this glass in the direction up towards 75 deg. The white vitreous enamelled internal top-reflector, in combination with the diffusing glassware, prevents any visible shadow from the lantern framework.

The prism surfaces of the refractors have glass covers, and the sides of the lantern are glazed with a fluted glass. This lantern, which is provided with two large doors, has proved easy to clean and, from the point of view of performance and appearance, is a great improvement over any previous lantern of comparable output. The original

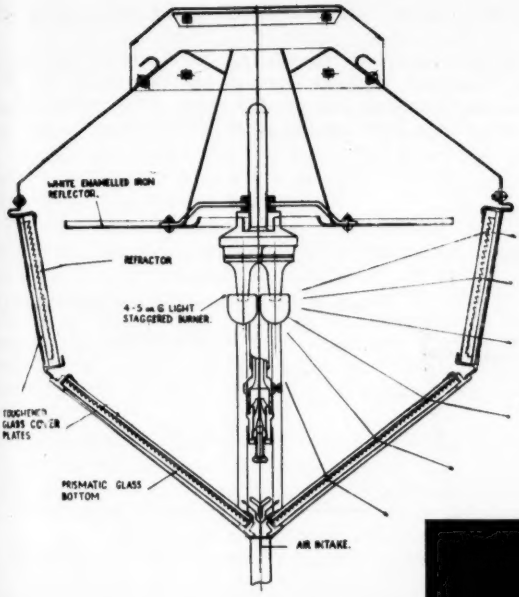
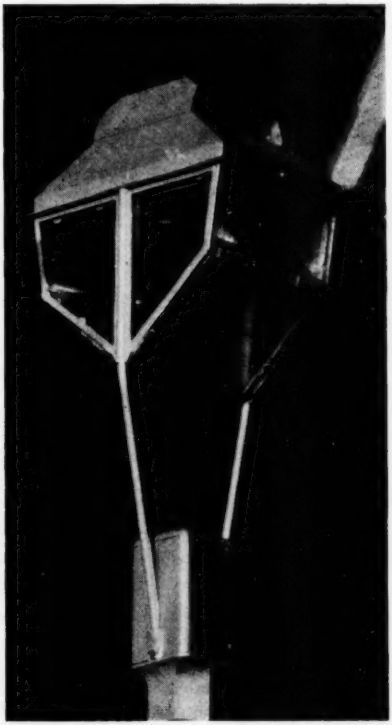


Fig. 4 *(Left)*. Cross-section of a modern Group 'B' refractor lantern.

absolute temperature of the mantle fabric. In this new lantern a directional fresh air entry of prescribed size was adopted, which produces a circulation of air within the lantern body such that the ingoing air is thoroughly warmed before reaching the mantles. At the same time, this flow of air is substantially tangential to the inner glass surfaces,

Fig. 5 *(Below)*. Modern Group 'B' refractor lantern.



burner equipment was of orthodox modern design, but has since been appreciably modified.

District tests similar to those described above were again made on an early installation of the new lantern. The results showed that depreciation was even less, the period between cleaning being extended, under certain conditions and for test purposes only, up to several months without undue deterioration in either performance or appearance.

An incidental advantage arising from this reduced attention to lanterns is the noticeably longer mantle life obtained, as a proportion of mantles is always broken during maintenance operations.

The amount of air flowing through a gas lantern is considerably in excess of that theoretically necessary to ensure complete combustion. An undue excess of air, however, will reduce the temperature of the burner and mantles with resultant reduction in light output, which varies approximately as the twelfth power of the

thus reducing the deposition of airborne dirt and lowering the temperature of the glass.

Mention has been made of the cover plates used to protect the refractor prisms from dirt. These cover plates have not, in district use so far, been sealed to the refractors, so that air has been able to circulate between the plates. It is interesting to notice that in a test carried out under district conditions, the dust deposit caused by

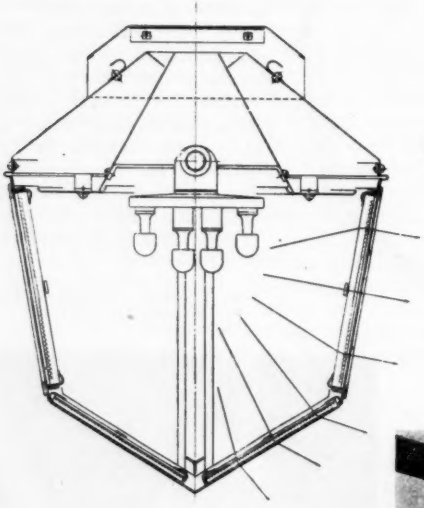


Fig. 6 *(Left)*. Cross-section of a modern Group 'A' refractor lantern.

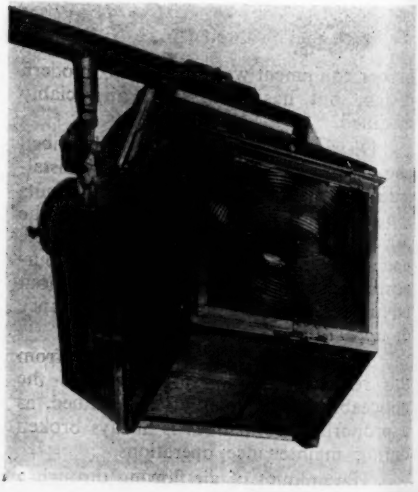


Fig. 7 *(Right)*. Method of mounting Group 'A' lantern and control equipment.

this circulation over a period of one year resulted in a reduction in light transmission of 20 per cent. for both inner surfaces of the glass "sandwich." The outer surface of the glassware of the lantern is reduced in temperature by this double glazing, eliminating to a marked extent the "baking on" of air- or rain-borne dirt.

This lantern, a completely post-war design, will be referred to again in describing recent street lighting installations of note.

(3.2) Group A Lanterns

Many of the principles of design mentioned above were of value in considering the development of lanterns intended for Group A lighting. The cross-section of a refractor panel lantern with such features is shown in Fig. 6. Compared with pre-war lanterns this design has advantages of simplified construction, improved maintenance and reduced manufacturing costs. The main refractor in this lantern is 12 in. x 8½ in., with the prisms disposed in an oval pattern above and below the optical axis. Below the axis the prisms are modified to "fill out" the polar curve below the direction of maximum intensity.

It was not unusual in the past to see a large gas lantern suspended well below a number of accessories to protect them from excessive heat. The modern lantern, on the other hand, is arranged to clip directly on to a horizontal bracket arm, and any accessories which cannot be located in the base of the column, such as an electric igniter, are placed at the side of the lantern next to the column where they are unobtrusive and accessible, and are subject to the slight temperature rise which is desirable to combat freezing conditions. The improvement in appearance and simplicity effected by this change in mounting is shown in Fig. 7.

(3.3) Control of Gas Consumption

An essential feature of these compact, modern lanterns is the provision of a constant pressure governor and calibrated gas ejector to hold the gas consumption in service close to the designed value. Any considerable excess of gas may cause damage to the glassware, as well as financial loss. Accuracy of rating has, therefore, been further improved by incorporating a spring-loaded clearing pin, which cleans the gas ejector mechanically without attrition in a few seconds' operation during normal maintenance.

This device may be used in conjunction with ejectors lined with stainless steel, which are virtually incorrodible and free from wear in service. It has been found

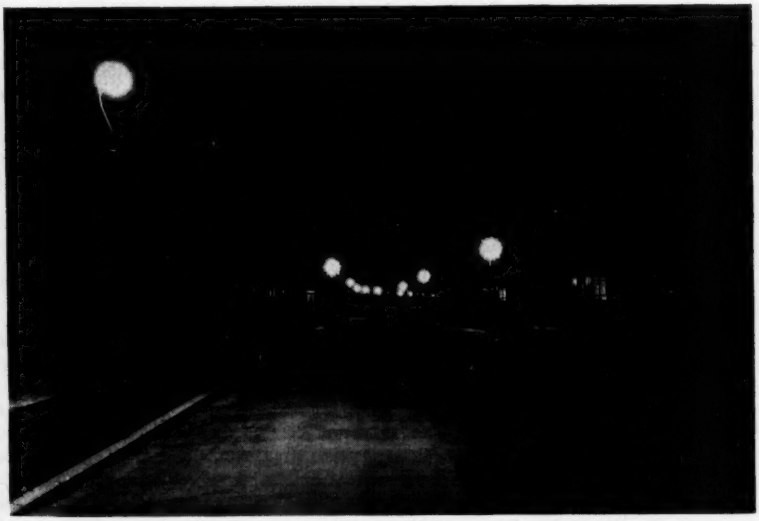


Fig. 8. New housing estate lighting with three-mantle reflector lanterns.

Fig. 9. High level Group 'B' lighting in London.

practicable to operate installations having this combination of ejector and clearing pin at gas consumptions appreciably closer to the exact rating than was previously possible.

(3.4) Simplification of Controls

It will be apparent from the description of gas control methods now employed that the need for adjustment here has been avoided and a sound basis laid on which consistent operation of the burner can be ensured, subject only to the attainment of the appropriate air-gas ratio. Many thousands of street lanterns are operating to-day with calibrated air entry ports in addition to virtually constant gas supply, and these have no means of air adjustment whatever. In general, however, it has been found convenient to provide means whereby the air adjustment can be correctly and easily made initially, and then securely locked, so that the setting is not disturbed even should the lanterns need to be dismantled. In contrast to the older lanterns, the modern lantern needs no adjustment apart from the initial setting of the air/gas ratio.

(3.5) Maintenance of the New Lanterns

It is probably true to say that most local authorities prefer that their lighting contract should include the provision of a nightly survey to ensure proper service to the public.

The normal scheme of maintenance, therefore, for the new lanterns, will envisage cleaning and clock winding at intervals of four weeks, with a percentage of burner cleaning, and a time allowance for any unusual attention such as may be caused by malicious damage or mechanical failure, together with a proper survey system. Such a maintenance schedule will compare very favourably with those still in common use with the older lanterns, which involve weekly, or fortnightly attention, and even then, owing to the possibility of disturbance of the various adjustments during maintenance, may result in a percentage of defects overnight calling for attention by the survey man. Atmospheric pollution in some industrial areas may necessitate revision of this scheme,

but these conditions adversely affect all types of street lighting equipment and the new designs will still show to advantage.

These maintenance economies are cumulative where a large number of modern lanterns can be installed in any one area, but it has been found even where there is a combination of old and new lanterns, that a worthwhile saving can be made, this being progressively increased as the conversion to new lanterns proceeds.

(4) Typical Modern Installations

Of the installations completed since the war, in which advantage of the new design features has been taken, it is possible to give here particulars of one or two only, which are typical of recent practice.

For the normal type of housing estate, opinions appear to differ greatly over the country as to the standards of lighting which should be provided. Some installations appear extravagant, others rather inadequate, although these are usually considerably above the standard common prior to the publication of the Ministry of Transport Final Report on Street Lighting.

In Fig. 8 is shown a night view of part of an installation of some 34 miles of housing estate lighting in one area which provides 1,470 lumens per 100 ft. linear, employing the reflector type of lantern shown in Fig. 1 at a spacing of 120 ft. and a mounting height of 15 ft. The use of the lateral adjustment provided for these reflectors shows to full advantage on the many bends which modern architects include in the plans of these estates. The standard of lighting is such that the faces of the houses, even when set well back, with front garden, pavement and grass verge, are adequately lighted. From the motorists' point of view also, headlights are unnecessary, and the assistance given by these lanterns in dense fog has been found useful.

As a contrast to installations planned to the latest recommendations, columns are often found at spacings of 150 ft. or 160 ft., which, for economic reasons, cannot be re-sited. In such installations a well-worthwhile improvement in illumination between the columns is often obtained by substituting the modern directional lantern for the older pattern.

A number of examples of the use of the Group B refractor panel lantern exists, and typical of these is the installation depicted in Fig. 9, where the lanterns have been fitted to existing columns in a London street carrying considerable light vehicle traffic. In this installation it was unnecessary to utilise the full light output of which this lantern is capable, and the source in consequence has been fitted with smaller mantles than normally and the gas rate correspondingly reduced. The excellent definition of the kerb lines resulting from this form of mounting can be seen. The visibility is more than adequate to ensure the rapid movement of traffic in all weather conditions, except heavy fog.

Space does not permit the illustration of any further examples of these installations, but engineers will be familiar with the recent Group A gas lighting schemes on London and Blackfriars Bridges, and on the eastern outskirts of London, in each of which a lumen output well up in the range of Group A lighting has been achieved.

This development work on low-pressure gas lanterns is continuing, and it is hoped to report, in due course, further improvements.

Discussion

DR. S. ENGLISH: In the first place let me say that I feel it a very great honour to have the opportunity of opening this discussion, not only because of my own friendship with Mr. Sugg but because I have played some small part in one of the developments which he has described.

Mr. Sugg has outlined some of the developments in gas street lighting in recent

years, but most of us will probably take our minds back a little farther than the time at which Mr. Sugg has started, to the days when gas street lighting was little more than beacon lighting. In other words, the lanterns were light sources rather than distributors of light, as is the case with these scientifically designed lanterns which we have seen this evening. The next stage was the addition of reflectors and refractors to those early simple lanterns. Those additions improved the light distribution considerably but, naturally, they were somewhat gadgety and, being so, they could not possibly be regarded as aesthetically correct. They were somewhat offensive to the eye and, like most gadgets, they were very easily put out of adjustment—and all street lighting engineers know that such things when maladjusted are not only useless but worse than useless.

These early developments were logically the proper way to go about trying to modify the light distribution and, after proving their effectiveness, the next thing was to start all over again and re-design in the manner that Mr. Sugg has described. But to start to re-design a series of gas street lighting lanterns from the beginning requires a certain amount of pluck and certainly a lot of faith, and we admire the faith and the pluck which Mr. Sugg must have had in starting the work which has led to the lanterns he has described this evening.

Mr. Sugg has referred a great deal to Class B road lighting and lanterns for that purpose. When we consider the enormous number of types of Class B roads which have to be lighted we are rather staggered. On the one hand, there are comparatively narrow roads, such as village streets, with practically no pavement and with the building line right up to the road edges. On the other hand, there are modern housing estates with reasonably wide roads with grass verges and pavements and often quite long gardens before you get to the houses, so that the width from house to house is quite large compared with the width of a village street. There are also tree-lined roads, and all street lighting engineers know that the lighting of tree-lined roads is a nightmare. The inhabitants will generally tell you that they would rather have the trees than the lighting, and what are you to do about that?

All these conditions require different types of lanterns, or different light distributions. Mr. Sugg has produced lanterns with such a wide spread of light that they cover the widest of these roads, and in the case of narrow roads the spread is more than sufficient, so that by accident or design he appears to have made standard lanterns to meet all requirements, and to that extent, at any rate, he is to be envied.

Another point that needs careful consideration arises when mounting lanterns at a height of 13-15 ft. and using directional lighting equipment. Glare must be avoided for at that height you cannot keep the light out of the line of sight. In some of the lanterns shown to-night glare has been reduced to a minimum, and the lanterns I have seen in service have not been objectionable from that point of view. Mr. Sugg's lanterns appear to meet all these requirements, and we congratulate him on the success which he has achieved—at the same time extending to him our best wishes for future developments of the same type.

MR. F. C. SMITH: I should like to say here and now that the gas industry owes a great debt of gratitude to Mr. Sugg and his co-workers for the work they have put into gas street lighting, and indeed for the contributions they have made to many aspects of gas engineering practice. Mr. Sugg has been all too modest this evening; he has passed over lightly the very difficult problems of aerodynamics which are involved in designing such lanterns as he has demonstrated and it may not be out of place to discuss these problems a little more fully. First of all, a gas lamp must be stable under all conditions of wind pressure. Secondly, air must be delivered free from combustion products at the primary airport of the burner and sufficient secondary air must be available at the mantle fabric to ensure complete combustion. This air must be

supplied in such a way and in such quantity as to avoid cooling the light source and avoiding any reduction in light output due to excessive cooling. The author has succeeded in fulfilling these requirements in lamps of small overall dimensions and of good appearance.

The meeting will know that the gas industry is under legal obligation to supply gas of declared calorific value. Gas manufacture is, however, a flexible process which permits of the industry taking up seasonal loads and daily peak loads by bringing into operation, as required, plant of different characteristics. The calorific value of the gas, whatever combination of process be adopted, will fulfil the statutory obligations, but the actual composition of the gas will depend upon the degree of admixture of gases from various types of plant. The actual character of the aerated flame is not independent of the composition of the gas and it is a feature of good burner design that the appliance shall be capable of dealing with gases of differing composition, within prescribed limits, without prejudice to the performance of the appliance. It is the practice in the industry to prescribe the mean value for gas characteristics which influence appliance performance and to state the standard deviation permissible from this mean value. It is, therefore, the problem of the designer to ensure that gas appliances operating on gas having characteristics within the prescribed limits shall be entirely satisfactory, and it will be realised how important to the consumer is the fact that the gas-making process is so flexible as to take up varying load factors without necessitating cuts in the supply. Frankly, I feel that this Society is not sufficiently aware of the immense amount of technical work that is carried out in the gas industry. Here again Mr. Sugg has been too modest, as he makes no reference in his paper to the fact that the burners he has designed are flexible enough to give the desired service without the need for readjustment. I would also like to congratulate the author on the measurements that he has made of the depreciation in light output from lamps operating under all weather conditions. The method which he has described which records the light output in the laboratory from a lamp operating outside and exposed to all weather conditions is most ingenious and of great value in determining desirable design features. This work has been supported by systematic measurements made by the North Thames Gas Board of the depreciations which occur in normal installations under all weather conditions.

I should like to speak for a moment about the economics of gas street lighting—and what I am about to say is true not only for gas units, but for all street lighting units, irrespective of the light source. Three charges go to make up the cost of street lighting. First, the capital cost of the equipment, erection and connection to the service; secondly, the cost of energy; thirdly, the cost of maintenance to secure the required light output throughout the life of the installation.

Those who have studied the economies of street lighting over the years know that in recent times the incidence of the charge has changed, and that labour for maintenance has become a predominant charge influencing markedly the total annual cost for street lighting. It is a fact that the lamps to which the author has referred this evening can run in London for five weeks without maintenance, and under these conditions the 70 per cent. considered to be desirable by the Code of Practice is achieved. A great factor in determining the value of any given street-lighting installation must be its ability to maintain a high and, as nearly as possible, a constant output without involving undue maintenance charges. This requirement has been achieved by modern gas street lighting units, and if any further proof were necessary this has been given by the author this evening. The claim is more than established by the fact that Unions have agreed that it is reasonable to ask men to maintain twice the number of lamps when these are of the new type.

The installations for which Mr. Sugg has given maintenance details were supplied with gas which was subject to the usual variations in gas characteristics for the area

concerned, and thus the 70 per cent. claim made includes any changes consequent upon changes in gas characteristics.

Lastly, I want to support the author's contention that certain roads can be lighted with units having a luminous output towards the upper end of the values prescribed in the Ministry of Transport report for Class B roads, and with 15-ft. mounting height to a standard which makes it possible for the vehicular traffic to proceed at 30 miles per hour without the use of head-lamps. This is a most important factor having regard to the present economic situation. Public Lighting Authorities are unwilling to pull down well-sited and good installations of the type to which I have referred, and to incur the extra expense involved by substituting units mounted at 25 ft. having the larger lumen outputs prescribed in the Code for Class A roads. With conditions as they are to-day, one has to approach the whole matter with a sense of realism. In my view the Code of Practice Committee should give careful consideration to this problem, and prescribe the types of roads and the conditions which must obtain in order that Class B lighting shall satisfy the requirements for roads carrying a reasonable volume of vehicular traffic.

MR. F. GRAHAM: Mr. Smith has raised the question of maintenance and maintaining 70 per cent. of the illumination from a street lighting unit. But how is that 70 per cent. to be determined? Is it to be determined by specifying the frequency of the maintenance of lamps or by illumination tests?

Dr. English referred to the early days and the use of a glass refractor as an addition to the lamps. I remember very well that in the fixing arrangements they had in those early days the ultimate aim was to have a dish. I am very pleased Mr. Sugg is proceeding with the "cut off" type of lamp and hope it will not be long before it is on the market.

At a previous meeting when Mr. Sugg presented a paper several members suggested that he should transfer his researches from gas to the hidden mysteries of electricity, but I am pleased to see him still with us supporting the gas industry which he has served for so long.

MR. A. G. PENNY: Mr. F. C. Smith has referred to variations in gas characteristics, and Mr. Sugg exhibited a slide shewing the variation in light output of lanterns at various points in the span against the number of weeks' unattended operation in service. During these tests, was the gas kept constant in its pressure or other characteristics? If not, it would be very helpful if the two effects could be separated so that we could have some idea as to how the light output of these lanterns varies with varying characteristics, and also with the time of operation. Is there any variation in the consumption of gas under these conditions?

Another point I should like to take up is the reference in the paper to a spring loaded clearing pin which cleans the gas ejector mechanically in a few seconds' operation during normal maintenance. Is that something which is done automatically, or is it a clearing operation carried out by the maintenance man? Also, could we have some information as to whether the life of the burner has been changed? How does it compare with the life of the more conventional types?

Finally, we should be interested to know the names of the street lighting installations which Mr. Sugg showed in his slides. I have not heard of them previously and I should like to see them.

DR. J. N. ALDINGTON: I should like to endorse what has been said in admiration of the work described to us to-night. We who have to do with light sources—which, incidentally, could not be made without gas—have many different types of electric lamp available, and we are constantly being urged by our colleagues to improve the

efficiency of our light sources. Yet we have been shown to-night how, with a single source—the incandescent mantle—developments have proceeded in such a way that the gas lantern has maintained its competition with electric lamp lanterns. Using the gas mantle—that apparently fragile structure of rare earth oxides—we have seen developments in lanterns which I think should serve as a further stimulus and inspiration to us all. That is certainly a lesson I have learned to-night.

MR. J. B. CARNE: I can add little to what Mr. Smith has said in congratulating Mr. Sugg on his achievement in producing such fine equipment. Having had a small experience in designing and making gas lamps, I realise the difficulties that Mr. Sugg has overcome and therefore I would like to add my congratulations to those of Mr. Smith and Dr. Aldington on his really fine practical achievement in developing the lanterns which he has described to-night.

DR. J. W. T. WALSH: Will it be possible for Mr. Sugg to give us to-night, or to add when the paper is printed, some information as regards the lateral spread of the light from these lanterns? With the mantles side by side I imagine that this spread will be considerable, and some information in the form of curves would be useful.

I was a little disappointed that Mr. Sugg said nothing about the work in progress on cut-off lanterns. It is cheering to know that work is going on in this direction, and perhaps Mr. Sugg may be persuaded to lift the veil a little.

MR. A. R. MCGIBBON: I had some passing interest in the gas industry for a time, and I should like to say how much I appreciate the paper because I know something of the work that goes on behind the scenes in the design of these lanterns and burners. One can compare the gas and electric lighting industries with the radio and the gramophone industries. When radio came along it was said that it would completely finish the gramophone industry, but we all know that in fact the sales of gramophone records were boosted. In the same way, when electric lighting came along it was said that gas lighting would disappear, but we know that the competition has acted as a stimulus. The designs of lanterns that we have seen to-night look very presentable and effective in the streets. They look far better than most pre-war designs; indeed, they look so presentable that one is almost convinced that they are electric lanterns!

It is interesting to hear of the progress being made in improving maintenance, because those who use gas lighting know that one of the difficulties to-day is maintenance. It is becoming more and more difficult to find men who are sufficiently skilled in the maintenance of gas lighting equipment, and anything that can be done to reduce the frequency of maintenance is a step in the right direction. A period of five weeks has been mentioned, but it would be better if it were ten weeks or even longer. It is also interesting to know that these lamps will automatically look after the variations in gas composition which occur to-day.

MR. P. RICHBELL: I would like to express my personal thanks to Mr. Sugg's firm. A good many of you may not be aware that the centenary of the firm was celebrated a few years before the war. During the whole of that time they have been pioneers in the development of gas lighting installations, at one time for indoor lighting and certainly still for street lighting.

There is one thing I would like to mention, however, although I hardly dare say it having regard to the building in which we are holding this meeting. Now that the standard of fittings for gas street lighting has reached such a high level, local

authorities might, by the adoption of these fittings for lighting their streets, considerably reduce the restriction on the use of electricity during peak hours.

MR. P. C. SUGG (replying to the discussion): Dr. English has made some very kind remarks, which I greatly appreciate; I think his association with these lanterns is quite obvious to all. I should like to thank him for the help he gave to me in designing them.

The gradual development in gas lanterns to which Dr. English referred, from the stage at which reflectors or refractors were added to the older designs up to the production of the modern lanterns which you have seen to-night, has, in my opinion, taken too long (largely owing to the intervention of the war), but it has been done, and one type of modern refractor panel lantern has now been in use for some three years, including the period of district trial.

Dr. English has referred to the widely varied requirements for lighting Class B roads. This is only one of the problems associated with the work of the public lighting engineer. I have spoken of the advantages of wide lateral spread in meeting these varying requirements, a point which is, I think, self-evident.

Dr. English has also commented on the care that is necessary to prevent undue glare when using a mounting height of 13 ft., but I would never advocate using these modern lanterns at 13 ft. The minimum height at which they have so far been used is 15 ft. By making the run-back at the top of the polar curve very rapid, as we have done with the refractor panel lanterns, it is possible to avoid undue glare. I am pleased to have Dr. English's confirmation of this.

With the low pressure gas mantle, the source brightness is only about 37 candelas' per square inch, and is approximately the same as that of the sodium discharge tube. This low source brightness assists in minimising glare.

Dr. Walsh has asked for figures of the lateral spread from these refractor lanterns. The smaller refractor panel lantern has a horizontal source approximately 6 in. long, and results in the intensity at 80 deg. from the vertical rising from 50 per cent. to the maximum, and back to the same value over a lateral angle of 40 deg.

I should like to thank Mr. F. C. Smith for his complimentary remarks which are very encouraging. He has given us an insight into the questions which arise from changes in gas quality due to the modern technique of gas manufacture. Mr. Smith dealt with that subject in a way that only he could, and it would be wrong for me to attempt to comment upon it. It is, however, a fact that these modern lanterns have to operate with these changing conditions of supply, and we now know not only that they will operate without noticeable variation under these conditions, but also that they are stable even when the pressure of the gas is less than normal. As soon as the pressure in the mains returns to normal, the operation of the lanterns returns to normal.

The possibility of Group B lighting providing sufficient visibility to avoid the need for the use of motor-car head-lights has been raised several times. I am confident from my own experience that this proposal is reasonable in many streets. I feel the matter should be thoroughly investigated when the Code for Group B lighting is considered.

Mr. Graham has asked how the depreciation of a street lighting installation is best determined. Whilst for the purpose of the work I have described in the paper measurements were taken at a large number of test points every night, in practice it would be sufficient for the contracting parties to agree that illumination measurements should be made at a selected test point at reasonable intervals of time. A suitable point would be at about 20 ft. from the column.

Mr. Graham also referred to cut-off lighting, in which I am very interested. We all know, however, that the comparatively close spacing at which cut-off units are used

has an adverse effect on the economics of the installation. However, I believe many of us feel that cut-off lighting is particularly suitable for such purposes as the lighting of arterial roads used by high-speed motor traffic, and that it will be widely used in the future.

Mr. Penny asked how variations in gas characteristics affected the performance of these units. For these tests, which were under district conditions, the gas supply was subject to variations in gas characteristics, and the results I have been given therefore include any variations in light output which might be attributable to this cause. Mr. Penny has asked the extent of this variation. I would assure him that it is so small that it can be neglected for all practical purposes. As far as I am aware, no one has ever measured it. The consumption of any gas appliance will vary slightly owing to the small changes which occur in the specific gravity of the gas with the change in its other characteristics. The use of a constant pressure governor and a calibrated ejector is assumed as in normal practice. The order of this change is probably 5 per cent. or less. Mr. Smith's contribution largely covered this point.

In regard to the spring-loaded clearing pin, I should have explained that this is operated by the attendant at the time of normal maintenance. In the absence of this device, the attendant would only clear the ejector if he thought the lantern was not functioning properly; with the device he can clean the ejector in three seconds, which he does every time he attends the lantern, thus avoiding a possible cause of variation in performance.

Mr. Penny also asked whether the life of the mantles in the modern lanterns has been changed. It is safe to say that the life has been considerably improved because the risk of accidental breakage has been reduced by the comparatively infrequent maintenance which these lanterns require.

The names of the street lighting installations which I have illustrated are as follows: (i) Part of a housing estate at Gosport; (ii) Guilford-street, Holborn; (iii) Romsey, Hants, where sodium has been adopted for the main roads and gas for all the other roads; and (iv) a new fly-over at George-lane, Wanstead.

I should like to thank Dr. Aldington, Mr. Richbell and Mr. Carne for their kind remarks, which are much appreciated.

I am very pleased that Mr. McGibbon took part in the discussion, for he has seen something of the laboratory work which lies behind the designing of these lanterns. At one time he carried out this type of work himself, and now he uses the finished article on a large scale. He confirms the importance of reducing the frequency of attention which is necessary for gas lanterns, and which is particularly desirable to-day owing to the high labour charges prevailing.

Register of Lighting Engineers

The Council have accepted the following applications for inclusion in the Register of Lighting Engineers:—

M. E. Broadbent, H. B. Burke, T. Catten, W. F. Pogson, H. D. Purvis, T. Roberts, T. L. Robinson, J. Sharp, W. H. Stewart, R. Winsby, A. B. Wright.

The Lighting of Buildings

Summary of a Paper read by

W. A. ALLEN, B.Arch., A.R.I.B.A. *(Member)*, and R. G. HOPKINSON, Ph.D., M.I.E.E., *(Fellow)*.

at a joint meeting of the Architectural Science Board of the Royal Institute of British Architects and the Society on March 13, 1951.

Seven years ago the Lighting of Buildings Committee, set up by the Building Research Board, published its Post-War Building Study No. 12, on the Lighting of Buildings. The report was an attempt to sum up, for the architect, what was understood of the technology of good lighting at the time. It went further than a summary of established practice, however, because it looked forward to the ultimate goal of good lighting, that is, to the lighting of the whole environment, and not solely to the lighting of the working plane alone.

This broader approach to the lighting of buildings brings together the two professions most concerned in its achievement. The architect and the engineer both work on a creative plane, disciplined by technique, but the architect treats the lighting problem only in its broad aspect, and leaves the detailed handling to the engineer. This has not always had happy results. The purpose of the work at the Building Research Station is to co-ordinate the lighting functions of both professions so that there is mutual understanding both of the respective techniques and of their objects and intentions.

Recent researches have permitted a clearer understanding of factors such as glare-discomfort, which are in the subjective rather than the objective domain of lighting. Techniques have been devised for the assessment of such subjective factors in terms of the physical quantities that control them. Again, the amount of lighting necessary for different types of work can be gauged, and to some extent the distribution of brightness in the field of view for best vision can be prescribed. Some conflicts occur, however, which demand a compromise. For example, the phototropic effect (the reflex action which directs the attention towards the brightest part of the field of view) is at its maximum when the visual task is bright and the surroundings are dark, but such conditions are not comfortable, and visual acuity is less good than when the surroundings are also bright. A judgment has to be made as to whether the work conditions demand maximum concentration at the expense of comfort, whether maximum visual acuity is necessary, or whether comfort is more important. Much depends on the nature of the work, and the duration of the task. Over and above such factors, the effectiveness of the lighting for its job, whether it is in character, whether the whole environment is suitably integrated as regards both lighting and colour, must be taken into account. Some of the factors can be planned in precise quantitative terms as the result of recent research, but some are still somewhat intangible, and must be attacked qualitatively. There is, however, no ground for giving insufficient weight to factors which are at present outside the scope of precise experiment. They must continue in the province of the designer until the engineer can add his co-operation.

Some Principles—A Summary

(1) *The object of attention should be the brightest part of the field of view.* The brighter it is, the better will detail be seen : the brighter it is relative to its backgruond, the easier will it be to concentrate on it.

(2) *The local surround to the object of attention, and the general background,*

The authors are with the Building Research Station, Garston, Watford The full text of the paper and the discussion is published in the April and May issues of the R.I.B.A. Journal.

should be of progressively lower brightness. When the utmost concentration is required, at the sacrifice of visual comfort, the steeper should be the contrast gradation between work and background.

When prolonged and monotonous tasks are involved, greater visual comfort may be indicated, and a gentle contrast gradation between the work and its background should be provided.

(3) *The sources of light should be limited in brightness and area, and should be graded into their surroundings.* The limiting values of source brightness and size are determined by the brightness of the environment and the position of the sources in the field of view. (See Petherbridge and Hopkinson, Trans. I.E.S. 15, p. 39.)

These ingredients of good lighting must all be present, but the balance will be different in a home, a hospital, a factory, or a school. They represent what may appear to be an extreme view; for example, they rule out totally indirect lighting. They demand a good standard of general lighting, with local, or "focal" lighting, on the work or the main visual task.

There is no guarantee that the group of principles is complete—one gap, for example, is the lack of mention of those factors which determine feelings of gloom, or of buoyancy. Some of these are known, but do not yet lend themselves to quantitative expression.

Some Examples

Examples of the application of these principles include the lighting of a woollen mill, where the mill was given a stimulating colour treatment, and mixed filament and fluorescent lighting was installed, with new designs of fitting. Filament "spots" enhanced the texture of the woven cloth, and added "sparkle" to the environment.

An art gallery was redesigned by distributing the natural daylight in favour of the objects of attention—the pictures—and ensuring both comfort and attention by a sentitive choice of reflection factors and colours of the surroundings, giving contrast and colour gradation.

School lighting has been studied in collaboration with local authorities and the Ministry of Education. New designs of lighting fitting, employing contrast-grading principles, have been completed. The distribution of natural light in classrooms, and the arrangement of windows to give the minimum contrast between the view of the sky, and the brightness of the surrounding walls, has been the subject of detailed study.

These, and other field trials of the set of principles, have all indicated that the start that has been made is on the right lines, although much needs to be known of the factors that determine the so-called "affective states"—fatigue, gloom, stimulation, etc. Good lighting will be achieved by a broad rather than a narrow approach, and the time does not yet appear to be ripe to constrain technology by "Brightness Codes" or other limiting methods. These will come when more of the relevant factors are understood. For the present, co-operation must be improved between, on the one hand, the architect and designer, inheriting as they do a long tradition of accepted qualitative practice, and, on the other hand, the engineer, who can devise a technology when practice is sufficiently understood in quantitative terms.

One major problem to be solved is the assessment of long-term psychological effects of lighting. The experimental conditions can rarely be controlled adequately over the period of the test. The bulk of routine work involved in accumulating sufficient observations to meet the dictates of current statistical procedure will often prevent inception of a long-term study by any but the largest research teams. These problems must be faced, if lighting technology is to be expanded to include the lighting of the whole environment.

Brightness Patterns and Visual Fields

By S. D. LAY, *(Fellow)*

Summary

Brightness patterns in the field of view, and their effect on visual efficiency, are examined in the light of research and of present trends in practice.

Two separate, but related, fields are analysed—one centred on the work, the other covering the environment.

Brightness patterns in each field and the relationship between the two fields are discussed.

It would both clarify research and simplify application of its results if it were possible to divide the visual field into simple practical zones of standard sizes rather than the varying arbitrarily selected zones found in different research work. The problem is examined and it is shown that there are four zones which could with advantage be standardised and used in future work.

Some observations are made on the significance of these zones and of their treatment in practice.

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(2) FIELDS OF VIEW.
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- (2.2) Brightness ratios between fields.

(3) VISUAL ZONES.
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- (3.3) Zonal characteristics and brightness ratios.

(4) RELATIONSHIP BETWEEN VISUAL ZONES IN SEPARATE FIELDS.

(5) PRACTICAL APPLICATION.

(6) CONCLUSION.

REFERENCES.

APPENDIX I: Observations on the Validity of Separating the Environmental View from the Work View.

APPENDIX II: Observations on a Typical Industrial Work View.

(1) Introduction

To achieve the most effective visual conditions, the lighting engineer must design and place his equipment so as to produce a specific brightness pattern in the field of view. There is, however, no generally agreed basis on which he can build this pattern, as was pointed out recently by Harrison(1).

There are two, apparently opposed, opinions on the optimum brightness distribution in the field of view. The first is based on the classic research of Lythgoe on visual acuity in 1932(2) and the later work of Schumacher on contrast sensitivity in 1940(3). Both workers found that task brightnesses substantially higher than those in the surrounding field were advantageous to visual performance throughout the normal range of illumination values. (Figs. 1 and 2.)

The other view, towards which practice has tended in recent years, has been propounded by Moon and Spencer(4) and by others in Great Britain and the United States. They maintain that, outside the critical detail of the task itself, the optimum visual condition is achieved by surroundings of uniform brightness. These conclusions are based largely on visual comfort and much thought has been directed towards the elimination of direct discomfort glare.

Recommendations of the Illuminating Engineering Societies in Great Britain and the U.S.A. show similar differences: in America low brightness ratios are required throughout the field of view(5), while the British code allows, as a low limit, that

Mr. Lay is with the Ministry of Labour and National Service, Australia. The manuscript was first received on January 29, 1951, and in revised form on March 22, 1951. Pending decisions on terminology at the 1951 C.I.E. Conference, it was decided that the term "brightness" should be used throughout this paper, even where "luminance" would be more in accord with the latest recommendations.

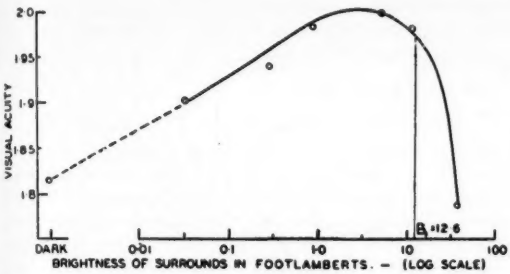

Fig. 1. Relationship between visual acuity and surround brightness (after Lythgoe).

the general illumination in lm./ft.^{2} may vary as the square root of the local illumination*([6]). Although these two views on the desirable brightness distribution throughout the visual field appear contradictory, they may in fact be regarded as complementary, as they relate basically to different fields of view.

(2) Fields of View

(2.1) Separation into Two Related Fields

In approaching visual problems in general there are two separate—though related—fields of view to be considered.

One field may be termed the "work view" in which the line of sight is, with very few exceptions, at an angle between 20 deg. and 75 deg. below the horizontal (Appendix I) and is confined to a small area for significant periods, which allows the visual field to be mapped with reasonable precision. In such conditions foveal vision is paramount and the data of Lythgoe and Schumacher may be applied, although the precautions mentioned in Section (3.3) should be observed.

The other field of view may be termed the "environmental view" in which during movement and periods of casual visual tasks—such as conversation and rest pauses during a task involving foveal vision—the gaze is along a line at, or near to, the horizontal. The gaze often moves quite rapidly and extensively over a wide horizontal range and parafoveal vision assumes the greater importance([7, 8]). Within this field low brightness ratios between significantly large areas are usually desirable for the sake of good appearance and to avoid frequent changes in adaptation, which may be uncomfortable, distressing and even dangerous.

The characteristics of the two fields are compared in Table 1.

Table 1.
Characteristics of two fields of view

Characteristics of Field	Work View	Environmental View
Main type of work	Critical tasks	Movement and casual tasks
Main type of vision	Foveal	Parafoveal
Size of working field	Small	Large
Direction of sight	20 deg.–75 deg. below horizontal	Near horizontal
Efficient brightness pattern	Graded (see Table 2)	Low brightness ratios
Main glare cause	Reflections of sources	Direct view of sources
Main glare effect	Disability	Discomfort

* It is interesting to note that this relation is substantially that found by Schumacher to be the *optimum* condition for contrast sensitivity in the range between 1 and 300 ft.-L.

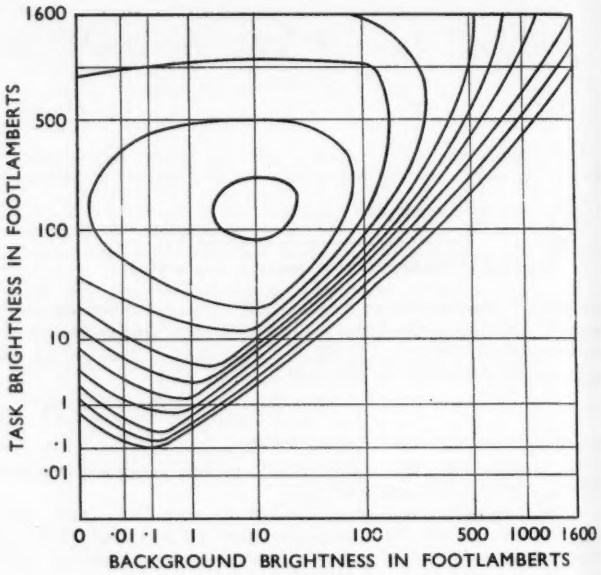

Fig. 2. Curves of equal contrast sensitivity.

(2.2) Brightness Ratios between Fields

There is no agreed brightness relation between the work view and the environmental view (1), although Luckeish and Moss have suggested 10 : 1 as a "safe and desirable" ratio of brightness of the work field to that of the surroundings. Referring to the use of a 100 : 1 ratio, they state that their recent researches seem to indicate that a "brightness ratio of 100: 1 might be too great "(9). This is generally consistent with Lythgoe's findings that visual acuity is a maximum when the surroundings are $\frac{1}{10}$ to $\frac{1}{100}$ as bright as the task (2), and with Schumacher's work on contrast sensitivity in the range of task brightness between 10 and 1,000 ft.-L. (Fig. 2).

Although these statements suggest the likely range of brightness ratios desirable between the task—that is, the critical detail together with its immediate surroundings—and the environment, no final conclusions can be drawn from the data for three main reasons:—

(i) Lythgoe's and Schumacher's results were obtained from laboratory performance tests and may need modification before being applied to practical work situations, taking into account the factors of time, attention, comfort, fatigue and other field effects (10).

(ii) Most visual tasks involve neither visual acuity nor contrast sensitivity alone : however, Lythgoe has stated that visual acuity data is applicable to most tasks, even where low values of contrast are also involved (11).

(iii) It is not possible to make direct comparisons between different researches on brightness patterns, as visual zones of widely different sizes have been arbitrarily selected by different research workers. For example, Lythgoe used a rectangular task field of about 1½ deg. with uniformly bright surrounds throughout the remainder of the field (2); Schumacher used a central field of 20 deg. having the same brightness as the task area and surround brightnesses of zero, 1 per cent. of task brightness, and the same brightness as

the task (3). Luckeish has used various zones; Logan uses a 60 deg. circular central field, divided into upper and lower zones by the horizontal diameter (12).

(3) Visual Zones

(3.1) Desirability of Standardisation

It is surprising that no attempt appears to have been made to define and name standard visual zones in the field of view. At present the words "Task," "Central Field," "Surround," and others, although frequently used, need definition whenever they have to denote a specific part of the field. Both the theoretical consideration of brightness patterns and their practical application would be greatly simplified if these zones and their names could be standardised.

However, if standardisation is to be of real value, the boundaries of visual zones must coincide, within reasonable limits, with actual boundaries in visual response or function.

The abrupt artificial boundaries of a practical specification cannot reproduce exactly natural visual boundaries which are not sharp, but rather zones of rapid change which, moreover, are somewhat ill-defined and vary between individuals.

As, however, the adoption of some system of zonal limits is necessary both for expressing the results of research and for applying these results in practice, the standardisation of zones whose boundaries approximate natural boundaries reasonably closely would have considerable practical advantages.

(3.2) Natural Zonal Limits

A study of the available data shows that the visual field can be divided into four zones having boundaries where rapid changes of response occur. These zones and their boundaries are:—

"Task"—a circular zone of 1 deg. diameter;

"Central Field"—a circular zone of 30 deg. diameter;

"Surround"—an annular zone extending from the central field to a diameter of 90 deg.;

"Peripheral Field"—the remainder of the field of view.

The eye's response to various phenomena (such as colour) is not strictly symmetrical about the line of sight: in the significant matter of glare, however, some recent work suggests that circular zones correspond closely with the effect, at least in the upper hemisphere (13). They are adopted here as a reasonable approximation to the blurred natural boundaries of visual response. The use of circular zones greatly simplifies the geometry involved in both the experimental and practical fields.

The four visual zones are discussed below:—

Task.—This term has been widely applied to the critical visual detail and its immediate background or surroundings. The limit of this area should lie within the foveal field, which subtends a visual angle of about 1½ deg. Various sizes of task area from 1 deg. to 2 deg. have been used: the choice of 1 deg. fulfils two necessary conditions—it lies wholly within the foveal field and yet covers the area of critical vision during fixation.

Central field.—The area immediately surrounding the task has commonly been termed the central field.

The natural boundary of this central field appears to lie quite closely to 15 deg. from the central point for the following reasons:—

(i) The knee of the visual acuity curve lies at about 15 deg. from the centre of the fovea (Fig. 3).

(ii) The knee of the disability glare curve, according to Holladay's formula,

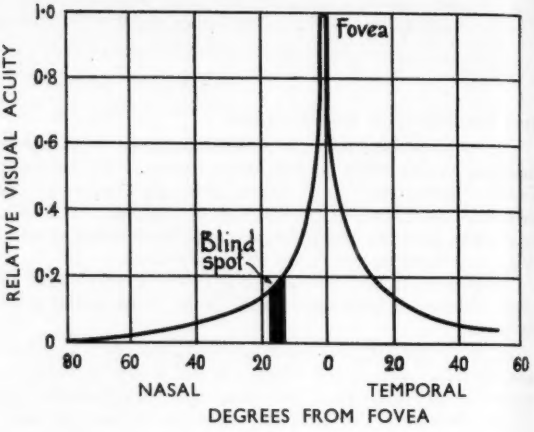

Fig. 3. Relationship between visual acuity and angular separation from fovea (after Werthiem).

lies at about the same place. Also, in practice, it is in this central field that reflected disability glare is most likely to occur.

(iii) The limit of the field of complete colour vision varies greatly, but for small areas of reasonable brightness lies at an average of about 20 deg. to 25 deg. from the central point, contracting with age to about 12 deg. to 15 deg. (14).

(iv) The eyes' limit of movement (fixation points) when performing everyday visual tasks does not usually exceed 13 deg. to 15 deg. from the point of central fixation (15).

(v) It has been determined experimentally that the brightness of the surroundings outside a central field 30 deg. in diameter have little influence on vision of the task, if there are no extensive areas of high brightness outside this zone (16).

Surround.—This term has frequently been used to denote an annular area surrounding the central field. It is generally applied to the whole of the remainder of the field of view, but there appear to be sound reasons for fixing the outer limit of this zone at 45 deg. from the central point:—

(i) Discomfort glare varies relatively little with displacement of the glare source from the line of sight up to an angle of 45 deg., compared with its rapid decline beyond this angle (13). Also, in practice, it is in this surround zone that direct discomfort glare is most likely to occur.

(ii) The eyebrows limit the view at angles greater than about 45 deg. to 50 deg. vertically above the line of sight. The vertical plane is the most important one to consider, as glare sources in the surround are generally above the horizontal and so approach the line of sight most closely in the vertical plane, when they also subtend a larger visual angle. This effect is illustrated in the values of Harrison's Location Coefficients (1).

Peripheral field.—The remainder of the field of view outside the surround may be termed the peripheral field.

Table 2.

Characteristics and brightness ratio limits for four visual zones

Zone Diameter	Zonal Characteristics				Allowable Brightness Ratios	
	Effect of zonal brightness on foveal acuity	Visual Acuity in Zone	Colour Vision in Zone	Most likely type of Glare	Within Zone	Average of Zone to Average of Task (Workview)
1 deg. Task	Maximum	Very high	Acute	Reflected–disability	High (between critical detail and rest of zone, otherwise, low)	—
30 deg. Central Field	Considerable	High (falling rapidly to edge)	Full	Reflected–disability	Low	1 : 1–1 : 5
30 deg.– 90 deg. surround	Little	Low	Little	Direct–discomfort	Medium	1 : 5–1 : 100
Peripheral Field	Very little	Very low	Very little	Flashing (and movement)	Fairly high	1 : 5–1 : 500

(3.3) Zonal Characteristics and Brightness Ratios

Once zonal limits are fixed, it is possible to set down the characteristics and desirable brightness ratios appertaining to the four zones, as in Table 2.

The high and low limits of brightness ratios given in Column 7 of Table 2 are tentative and *are applicable to the downward work view only.* They are based on the present available information from laboratory performance tests [2, 3] and

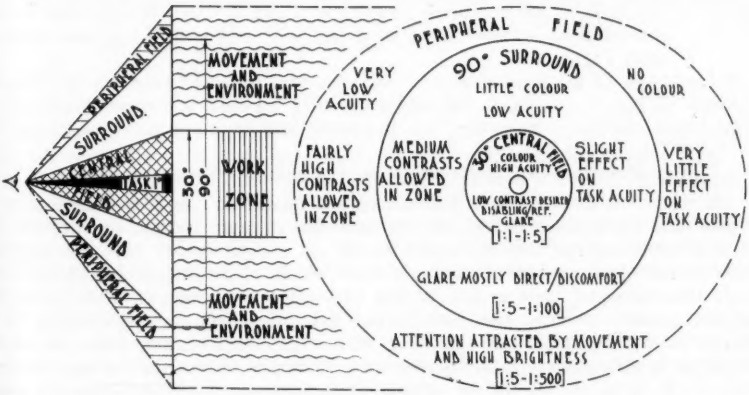

Fig. 4. Graphical representation of visual zones. Figures in brackets refer to zone/task brightness ratios.

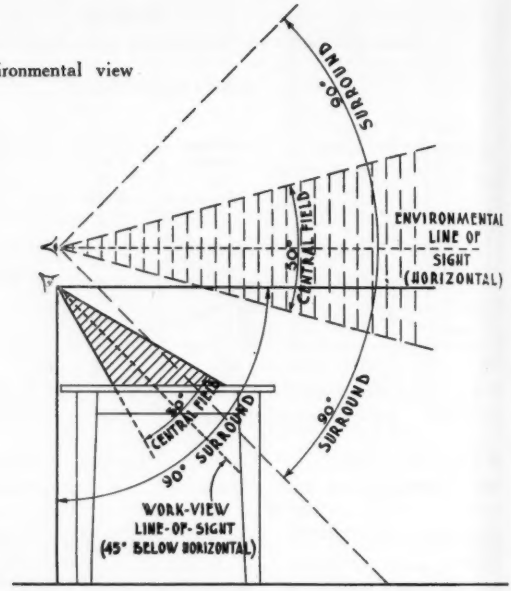

Fig. 5. Relationship between environmental view and work view.

are subject to the limitations described in Section (2.2) (i). They should be applied with the following provisos:—

1. No zone should have an average brightness appreciably higher than the adjacent more central zone.
2. Changes in brightness should generally be gradual—there should be no sharp boundaries between large areas of brightness.
3. Environmental and safety considerations dictate that the minimum average brightness of each of the two outer zones should never be less than 2-3 ft.-L. This brightness should be raised if visual tasks in the environmental field demand it, even if this will make the brightness ratio less than 1:5.

Information of the kind given in Table 2 is well suited to graphical presentation, as shown in Fig. 4, in which the broad division between the zones important for critical vision and those important for movement and environment is made apparent.

(4) Relationship Between Visual Zones in Separate Fields

The four visual zones described above are related to the characteristics of the eye and thus apply to any field of view and line of sight, but in practice the task area can almost always be considered to be on a sight-line at least 20 deg.—and usually about 45 deg.—below the horizontal, which places the centre of the (horizontal) environmental view in one of the two outer zones of the work view. The brightness pattern in these two outer zones has little effect on the visibility of the task (provided that very high values or very large areas of brightness are absent) so that the low brightness ratio technique [4, 5] can be applied in the environmental view. Task visibility will not be affected if the average brightness does not greatly exceed one-fifth of the task brightness. Reading from chalkboards in schools is perhaps the most important exception to the downward work view. Here the board becomes

an alternative central field to that on the desk; the remainder of the field becomes the surround (and peripheral zone) for both tasks.

Conversely, the central field of the work view lies in one of the two outer zones of the environmental view, and because of the changed angle of the head and the increased distance of the eye from the task this zone of high brightness occupies only a small part of the two outer zones in the environmental view (Fig. 5). In fact, on looking up from a desk or bench, the task is often completely hidden by the configuration of the face. If the limits of this patch of high brightness are not too sharply defined, it can have little or no effect on visibility in the environmental view.

(5) Practical Application

The characteristics of the four visual zones, shown in Table 2, and the separation of the work view from the environmental view, suggest an approach to many visual problems that differs from present practice. Three industrial examples are given below:—

(i) Preference should be given to using general lighting for environmental comfort and safety in conjunction with "work field"* lighting to provide the most suitable conditions for seeing the task, rather than to effect a compromise by the use of a higher value of general lighting for both purposes.

(ii) Consideration may be given to a more varied decorative treatment of walls (and other surfaces outside the central field of the work view), as their function is related to the environment and not to the task (except indirectly during work pauses).

(iii) In most industrial processes where material is shaped, e.g., metal turning, the whole of the 1 deg. task area lies within the object being worked (Fig. 6). Any background of considerable contrast in brightness *or colour* behind this object and within the limits of the Central Field will hinder—not assist—seeing the critical detail against the background of the object itself.

On the other hand, artificial backgrounds contrasting with an object in brightness and/or colour are of great help where the object itself is the critical detail, and its presence or absence, position or profile, constitutes the visual task, e.g., counting small objects, textile operations involving yarn breakage, and coil winding.

(6) Conclusion

Two fields of view must be considered in any general approach to visual problems. One, the work view, is primarily concerned with the performance of critical visual tasks; foveal vision is the paramount factor, and the task is confined to a small area for significant periods. The other, the environmental view, is associated with movement and casual seeing, and parafoveal vision is the more important consideration. In the work view, the line of sight is, with few exceptions, at an angle of 20 deg.—75 deg. below the horizontal, while in the environmental view it is usually at or near to the horizontal.

The two fields should be considered separately, other than to ensure a reasonable brightness ratio (which may vary within wide limits) between them. It is safe to apply the performance data established by research to the work view if some simple

* The term "work field" lighting is used here rather than "local" or "supplementary" lighting to emphasise that such lighting should not necessarily consist merely of an adjustable fitting, but should be adequately designed to suit its specific purpose.

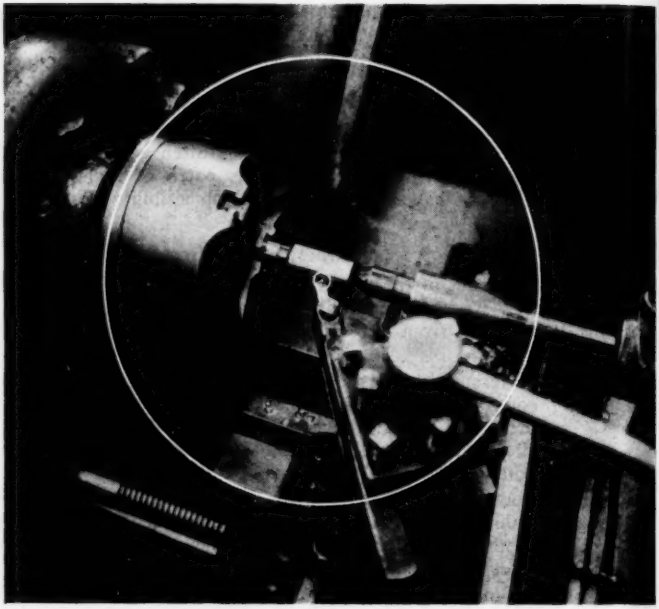

Fig. 6.
Typical work view with circles showing 1 deg. task and 30 deg. central fields.

precautions are observed. The low brightness ratio technique may be applied to the environmental view.

There are four concentric zones in the field of view, whose circular boundaries closely approximate zones of rapid change in visual response. The specification of brightness relationships within each of these zones and between one zone and another enables the brightness pattern throughout the visual field to be defined within the limits required to effect a close control of visual conditions. Sufficient data on the desirable brightness relationships to ensure good visual conditions in and between zones is available at the present time, but further research is necessary to establish precisely optimum relationships in varying circumstances. Investigation is also required into the relationship between the work view and the environmental view.

The standardisation of visual zones should materially assist discussion of the problems involved and the definition of research projects. It would also render the results of investigations more useful both by making possible direct comparison with similar work and by facilitating practical application in the field.

I wish to thank Mr. J. C. Lowson and Dr. A. Dresler for their constructive criticisms of this paper in its draft forms.

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Appendix I

Observations on the Validity of Separating the Environmental View from the Work View

A considerable number of observations in various work places has been made by the author to confirm the existence of the two fields and the validity of treating them separately; few exceptions were noted to the general rule that in the working position the line of sight was 20 deg. or more below the horizontal. It was generally between about 35 deg. and 60 deg. Where the line of sight was above 20 deg. below the horizontal one or more of three conditions usually existed which indicated that the general conclusion was not affected :—

(i) The visual task was neither concentrated nor critical, e.g., the reading of instruments, the minding of process plant, labouring work, etc.
(ii) Movement was involved, such as vehicle and crane driving.
(iii) The plant or the work itself created an artificial background, e.g., large plant erection work, car body finishing, transport maintenance pits, some materials handling operations, glass bottle inspection, several textile operations such as perching and some warping, paper and newsprint machines, etc.

The most important exception not covered by these three conditions is that of reading from the chalkboard in schools. Others are hosiery linking, and welt sewing and rough rounding in shoe manufacture. Industrial tasks involving manipulation at or near eye level are rare because of the muscular fatigue involved and the rates payable for their performance are always higher as determined by time and motion study. Fig. 7 shows typical work view angles for both machine and bench work.

Weston has pointed out[17] that "it is quite possible to have good general lighting of a factory and unsatisfactory illumination of the work, or good illumination of the work and unsatisfactory environmental brightness." In offices the work view is frequently satisfactory and the environmental view so unsatisfactory that although a full day's desk work produces no ill effects, a few hours of conference involving only casual seeing in the environmental view (in which light sources are visible in the surround) will cause quite severe symptoms of visual fatigue. It is possible that this experience has led industrial lighting engineers to place undue importance on the environmental view, and thus on direct discomfort glare, although the reflected disability glare that frequently accompanies the work view is of greater moment in the factory.

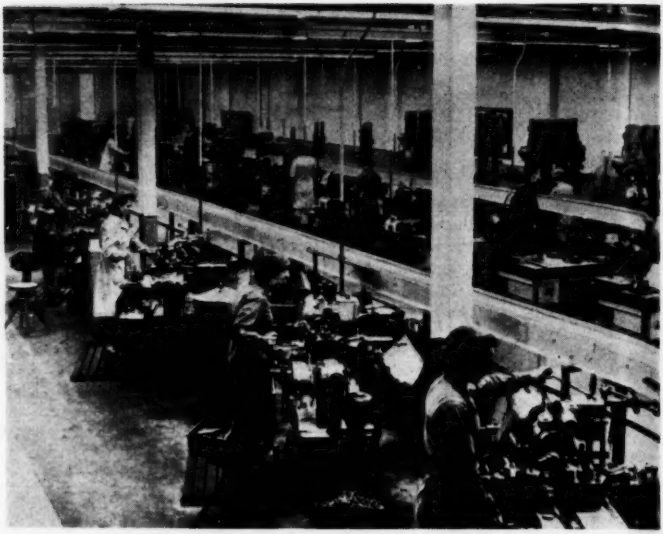

Fig. 7.
Typical work view angles for machine and bench work.

Appendix II

Observations on a Typical Industrial Work View

A photograph of a typical work view is reproduced in Fig. 6. It was taken from the recorded position of the bridge of the nose of the operator (26 in. from the tool point). The line of sight was about 35 deg. below the horizontal and approximately 20 deg. to the normal to the lathe in plan.

Circles have been described about the 1 deg. task and the 30 deg. central field; the 90 deg. surround covers more than the remainder of the figure. A photograph, however, cannot convey accurately what the eye sees and even less how the brain interprets the visual stimulus. For example, the state of accommodation and convergence of the eye at a focal distance of 26 in. destroys acuity in front of and behind the plane of the task, while the falling off of visual acuity with increasing angles to the line of sight and other factors limit perception in the plane of the task. The tool-holder boss appeared slightly more hazy to the eye than in the photograph and the swarf shield much more hazy.

Several interesting points emerged from an examination of this work view:—

(i) The task area, within which high contrast between the critical detail and the background is desirable, lay wholly on the metal being worked and on the tool, so that an artificial background (such as a buff-coloured paint finish) can be of no assistance. Any considerable contrast of colour or brightness in the central field outside the task area would be disabling or distracting. Beyond the central field, however, it may well be advantageous to use a colour roughly complementary to that of the material being worked to assist in colour readaptation and restfulness during work pauses.

(ii) The area covered by the central field in this particular case, as in most cases, was not amenable to unifying treatment by painting or other artificial means. Furthermore, it appears unnecessary to attempt any such treatment except

when it is close behind the task; a background such as the swarf shield is, as stated above, out of focus and very hazy.

(iii) It is apparent that disabling reflected glare is a problem within the 30 deg. central field. This was obvious photographically—in fact the tool-holder boss had to be dulled to enable a successful photograph to be taken.

(iv) The brightly coloured control buttons are in the surround and thus outside the sensitive colour field. They were quite inconspicuous when looking at the work, but jumped into prominence when brought within the central field, as required for their operation.

(v) The 90 deg. surround, which is the more sensitive portion of the environmental and visual warning region (Fig. 6), includes the lathe itself, the swarfshield, parts of the floor and other machines and benches. It just includes the lowest portion of a window, but it does not include any artificial light sources and only an insignificant area of lower wall, so that the brightness pattern formed by the walls and light fittings has little or no effect on seeing the work. This statement does not, of course, refer to the profound effect on visual effectiveness of the quality of the *illumination* on the work provided by the light sources and modified by the walls and other surfaces.

The Annual General Meeting

The annual general meeting of the Illuminating Engineering Society was held at the Royal Institution, Albemarle-street, London, W.1, at 6 p.m., on Tuesday, May 8, 1951. The President, Mr. L. J. Davies, was in the chair. The Secretary having read the notice convening the meeting and the statement of the auditors for the past year, it was agreed that the minutes of the last meeting be taken as read, and were approved.

Report and Accounts for 1950

The President then presented the Report of the Council for 1950. (See *Transactions, Vol. XVI, No.* 4, 1951). The President drew attention to the revisions to the Articles of Association, which now entitled the Society to have five vice-presidents serving for a maximum period of two years instead of three serving for three years. He also said that, following the success of the Summer Meeting held at Buxton in May, 1950, the Council were making arrangements for a further meeting to be held at Eastbourne in May, 1952. He reported that the Registration Board were now up to date with applications, and that at the end of 1950 the names of 212 members had been included on the Register of Lighting Engineers.

The President pointed out that though the accounts for the year under review showed a reasonable excess of income over expenditure, the Council were concerned with the effect of rising prices on the Society's budget. He said that it was expected that in the current year income would only just keep ahead of expenditure, but that in view of rising costs steps would have to be taken to raise the income of the Society, though it was hoped to do this without increasing the subscriptions of ordinary members at present.

The adoption of the Report was proposed by Mr. W. Robinson and seconded by Mr. F. M. Hale, who also expressed appreciation to the Council for their services during the year. The resolution was put to the meeting, and the Report was declared carried unanimously. The President, on behalf of the Officers and Council, thanked the meeting for their expression of thanks.

Election of Officers and Council

The President reported that there had been no independent nominations for

officers, and the following were therefore declared elected:—

President.—Mr. J. G. Holmes.

Vice-Presidents.—Dr. W. J. Wellwood Ferguson; Mr. A. G. Higgins; Mr. E. C. Lennox; Mr. L. C. Rettig; Dr. W. S. Stiles.

Hon. Treasurer.—Mr. W. J. Jones.

Hon. Secretary.—Mr. H. C. Weston.

Hon. Editor of Transactions.—Dr. W. E. Harper.

The President also reported that, following the announcement of the names of the Council's nominations to fill vacancies on the Council from October 1 next, two independent nominations had been made, with the result that the following were elected:—S. Anderson, P. Hartill, T. S. Jones, K. R. Mackley, A. R. McGibbon, C. W. M. Phillips, J. F. Stanley, W. D. Wright.

Honorary Membership

The President then recalled that under its constitution the Society is entitled to not more than six Honorary Members, there being at present only two. The Council had decided to confer Honorary Membership on Dr. John W. T. Walsh in acknowledgment of his eminence in the field of photometry and illuminating engineering, his long and sustained and outstanding service to the Society and his work for both the National and International bodies concerned with the science and technology of illumination. A certificate recording the award was presented to Dr. Walsh. Dr. Walsh, in acknowledging the presentation, said how much he had enjoyed his association with the Society and its members, and how much he appreciated the good fellowship and co-operation which he had always found within the Society.

This concluded the formal business of the meeting.

The President then called upon Professor E. N. da C. Andrade, Director in the Royal Institution, to give his lecture entitled "Luminescence." After the lecture a vote of thanks to Professor Andrade was proposed by Dr. H. Buckley and seconded by Dr. W. D. Wright, after which the meeting was closed with an expression of thanks to the Managers and Director of the Royal Institution for their hospitality.

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

SUSTAINING MEMBERS:—

Hivac Limited.....*Representative*: C. R. Sterling.
Greenhill Crescent, Harrow-on-the-Hill, Middlesex.

Sign Components Limited.....*Representative*: J. Jones.
121-3, Camden High Street, London, N.W.1.

CORPORATE MEMBERS:—

Anderson, J. R. .....9, Bedford Road, Sutton Coldfield, WARWICKS.
Barber, M. .....32, Carlton Road, Ashton-under-Lyne, LANCS.
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Blake, A. .....84, Montgomery Road, SHEFFIELD, 7.
Blatchford, W. H.....38, Athelstan Road, Whitchurch, GLAM.
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Cole, L. W. .....71, Old Park Road, Palmers Green, N.13.
Connell, J. .....46, Beaconsfield Street, LIVERPOOL, 8.
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Duncan, W. E. .....154, Orton Road, Carlisle, CUMBERLAND.
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Emsley, K. .....33, Fern Hill Road, Shipley, YORKS.
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Farr, A. G. R. .....196, Casewick Road, W. Norwood, S.E.27.
Fowler, P. W. R. .....80, Chamberlain Avenue, Penkhull, STOKE-ON-TRENT.
Francis, V. J. .....Research Laboratories, The General Electric Co., Ltd., Wembley, MIDDX.
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Cullingworth, J. .....22, Recreation Place, Holbeck, LEEDS, 11.
Glendinning, T. E. A. .....17, Storie Crescent, Lupset, Wakefield, YORKS.
Greenhalgh, D. E. .....13, Rossdale, Sutton, SURREY.
Hazelip, D. W. .....5, Burlington Road, LEEDS, 11.
King, E. .....7, Tunstall Street, LIVERPOOL, 7.
Marsh, R. D. .....42, Temple Avenue, Shirley, Croydon, SURREY.
Miller, H. G. M. .....Knowepark West, Bo'ness, W. LOTHIAN.
Taylor, J. E. .....38, Foundry Approach, Harehills, LEEDS, 9.
Twitchen, D. R. .....26, Graham Road, Harrow, MIDDX.
Walker, D. .....18, Hyde Park Terrace, LEEDS, 6.

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